

“WHERE DO I START?” RIDES TO SPACE FOR SCIENTIFIC AND ACADEMIC PAYLOADS

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ABSTRACT. The launch problem for small payloads is nowhere as serious as it is for scientific and academic users, who cannot tap the purchasing power available to spacecraft funded by the military and large corporations. The options available for the researcher at a university who has an instrument or a spacecraft are limited, sometimes depressingly so. Dedicated vehicles are usually unaffordable, and secondary payload opportunities require meeting a host of requirements, from payload design to timing to integration, dependent on the needs of the primary payload.

In this paper, the authors survey the options available and answer the question, “Where do I start?” Sources of potential rides, including NASA, military, commercial, and non-U.S. programs and organizations were surveyed. The results are presented here, along with recommendations for an improved process which, at low cost, could improve the “matchmaking” system and simplify the obstacle course faced by spacecraft and instrument developers today.

Introduction

While the technology to reduce the size and increase the capability of small scientific and academic satellites continues to advance, the options for launching those satellites have not improved appreciably in decades. While waiting for the promised era of reusable launch vehicles (RLVs) and other new options to arrive, what can satellite builders do?

While there are no easy answers – no cheap, routine, available, paperwork-free rides to space – there are several options. The focus of this paper is on the options payload developers in the U.S. can pursue to get small (under 100 kg), free-flying scientific payloads into orbit.

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Who To Call First

The payload developer can start by approaching two government programs which aim to help in providing rides to space.

NASA Access to Space Office

The online Access to Space Help Center allows users to examine projected flight opportunities on NASA-sponsored Expendable Launch Vehicles (ELVs), spacecraft buses, and Space Shuttle carriers. The known opportunities are in the Web site’s Mission Database. (For all Web addresses, and other contact information, see the Resources section at the end of this paper.) For each mission, a point of contact is included in the database. Other useful tools on the site are a Tool Kit with information on types of launch vehicles and a Flight Dynamics Web Tool which provides orbital analysis. The user can access

abridged User's Guides for candidate vehicles and see drawings of interface hardware.

While unquestionably useful, the Access to Space database is not quite an all-in-one tool. Most notably, it does not include non-U.S. flight opportunities. (The ATS Group plans to add this data in a future upgrade.) There is also no parameter the user can input concerning cost, and no cost information. Granted, launch costs vary considerably, depending, for example, on whether the user needs the launch provider to handle all aspects of payload integration. Some launch providers, notably government agencies, also charge different rates depending on whether the payload developer is government, commercial, or nonprofit. Still, adding some guidelines on this subject would be a useful enhancement to the Database.

Space Shuttle Rides

NASA operates one launch vehicle of its own, the Space Shuttle. The agency's Shuttle Small Payloads Project (SSPP) prepares and flies small payload carrier systems for the Shuttle. The Hitchhiker, Getaway Specials (GAS), and Space Experiment Module (SEM) support NASA payloads as well as experiments and satellites from other agencies, universities, and foreign organizations. Payloads can range from 23 to 2270 kg. (Users can determine what kind of accommodation is needed for a given payload on the Shuttle by using a tool on the Access to Space Web site.) The Hitchhiker system can eject microsatellites; the other options are for payloads remaining with the Shuttle. SEM is specialized for carriage of experiments from grade schools and universities. It is uncertain what will happen to the availability of SSPP opportunities with the anticipated reduction in Shuttle flight rates, but they will certainly not increase.¹

DoD Space Test Program

Spacecraft developed with Department of Defense (DoD) sponsorship may be eligible for launch under the Space Test Program (STP). STP, part of the Air Force's Space and Missile Systems Center (SMC), can schedule launch of

spacecraft or experiments on ELVs, the Shuttle, or piggyback on other spacecraft. (The STP office is effectively the primary DoD manager for all secondary payloads.) STP-arranged flights are paid for by DoD if the payload is approved by DoD's Space Experiments Review Board (SERB). STP can also provide launches to non-SERB payloads, although the user must reimburse the costs.

The Secretary of the Air Force for Acquisition (SAF/AQ) convenes the SERB each year to produce a prioritized list of experiments, which is then provided to the STP office. Only a fraction of the proposed experiments can make a flight on the small number of STP-funded rides, but it may still be worth the effort to find a DoD sponsor for those payloads which offer some utility for defense purposes. If the experiment requires a free-flying satellite, the STP will handle contracting for the development of a suitable spacecraft, integration of the experiment, and launch. The STP coordinates hosting and integration of experiments which can fly piggyback on other satellites or on the Space Shuttle.

The STP flies about one-quarter to one-third of the payloads making the SERB list annually. The program office juggles a limited budget, the SERB priority list, and the flight opportunities. Experiments requiring Shuttle flights, for example, are more likely to get a ride soon than a full spacecraft with a dedicated launch vehicle, even if the latter has a higher priority.²

An experiment submitted to the SERB can be proposed by anyone, but the developer must find a DoD sponsor. Any DoD laboratory (such as the Air Force Research Laboratory (AFRL) or its counterparts in the other services), research center, test range, or product division can sponsor a payload.³ After the sponsor submits a form describing the experiment to SAF/AQ, the experiment is reviewed at the next SERB and placed on the SERB priority list. Priorities are assigned based mainly on the payload's relevance to DoD requirements. For those experiments which make the cut for launch opportunities, the STP provides support for up to a year of on-orbit operations.

Universities Space Research Association

A useful resource outside the government is the Universities Space Research Association (USRA). USRA has no formal database of launch opportunities, but does try to match researchers with launchers. “We have a reasonably good feel for who’s doing what” in terms of launch opportunities, says Jim Finnegan of the Association’s Space Technology Development Office.⁴ On occasion, launch vehicle builders have come to USRA to offer space that would otherwise be wasted.

Launch Vehicles

Payload developers can also approach launch vehicle builders and marketers directly.

American Small Launch Providers

If a dedicated launch of a microsat is required, the smallest American vehicle in operation today is the Pegasus XL from Orbital Sciences Corporation of Dulles, VA. The Pegasus XL can lift 190 kg into 800-km sun-synchronous orbit (SSO) and 443 kg into low inclinations. An unusual feature of the Pegasus XL is that it is air-launched, meaning all inclinations and a variety of launch locations are available. Secondary payload opportunities are provided. Up to eight 43-kg Orbcomm communications satellites have been orbited on a single mission, and scientific microsats have been carried as primary and secondary payloads.

NASA has used Pegasus for several science satellites, most recently the High Energy Spectroscopic Imager (HESSI) in February 2002. A dedicated launch costs in the neighborhood of \$15 - 18M, depending on variables such as what services the customer wants Orbital to provide.⁵ Orbital also developed the Minotaur, a small ground-launched vehicle (cost: about \$14M) based on Minuteman ICBM stages. Minotaur is used by

the Air Force’s Space and Missile Center (SMC) for DoD-sponsored payloads. Finally, secondary payloads have been carried on the company’s larger Taurus launcher.

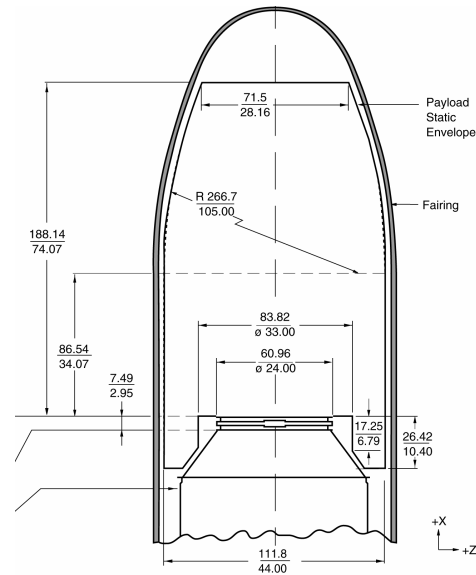


Figure 1. Pegasus XL payload fairing, also used on the Minotaur. Dimensions are in cm/inches. (Orbital Sciences)

Secondary flight opportunities are available on some of the larger American ELVs. For example, a November 2001 launch of Boeing’s Delta II carried a secondary payload – the Munin microsatellite from Sweden – in addition to two primary payloads. Flight opportunities can be found via the Access to Space Web site or by contacting the vehicle manufacturers.

The DoD STP is planning to place some of its future launches on the Evolved Expendable Launch Vehicle (EELV) competitors, the Boeing Delta IV and Lockheed-Martin Atlas V. The EELV is required to have the capability to carry secondary payloads, though availability and cost must be worked out for individual flights.

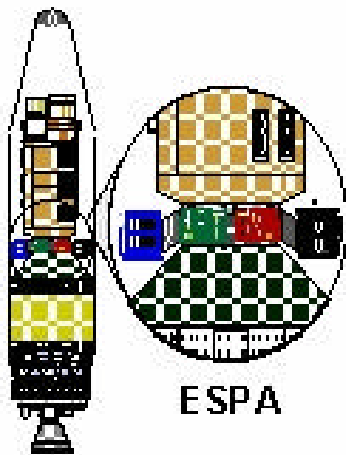


Figure 2. EELV Secondary Payload Adapter (ESPA) with microsats. (USAF)

The launch vehicle providers may use their own adapters or the AFRL-developed EELV Secondary Payload Adapter (ESPA). The Air Force has projected the cost of a microsatellite launch via EELV could be as low as \$700,000.⁶

Rides Between Orbits

Many commercial launches place large comsats into geosynchronous transfer orbit (GTO). A logical addition to the smallsat launch capability would be a propulsion module which could break off from the core vehicle and deposit a smallsat in LEO.

This is now being pursued by AeroAstro, which has one customer so far for its SPORT (Small Payload ORbit Transfer) module. SPORT minimizes its propellant requirements by using aerobraking to provide most of the energy used in the maneuver. The SPORT is intended to cut the total cost of access to LEO considerably, although the company declines to publish a figure because of the variety of possible SPORT configurations and other variables affecting each launch.⁷ The first launch is expected in late 2003 aboard an Ariane 5 (see below). AeroAstro will handle the coordination with the launch vehicle maker and other payload owners for the prospective user.

Even half or a third of the price of today's dedicated small launch vehicles remains out of the reach of many payload developers. Like all secondary systems, SPORT rides are at the mercy of the interests of the main payload developer and the launch provider, and must be launched when the main payload is ready. Still, every new option is an improvement, and SPORT provides a greater degree of freedom in selecting the smallsat's orbit than is available on secondary rides with main payloads going to LEO.

Another company, SpaceDev, is developing the Orbital Maneuvering and Transfer Vehicle (MTV), a family of propulsion modules which can provide changes in orbital altitude of inclination.

Opportunities overseas

The use of foreign launch vehicles involves a tradeoff. Many are cheaper than American counterparts, especially for primary payloads. The downside is the need to deal with the requirements imposed by the U.S. government's International Trade in Arms Regulations (ITAR).

The ITAR process includes three steps, which may be carried out in parallel:

1. Negotiation of a Technical Assistance Agreement (TAA) with the launching company. This must be approved by the Defense Threat Reduction Agency (DTRA).
2. Requesting an export license from the Office of Defense Trade Controls (ODTC) of the U.S. State Department.
3. Preparation and approval of a Technology Transfer Control Plan.

United Start Corporation in Costa Mesa, CA has the marketing rights for several small vehicles available from Eurasian countries. The Kosmos (or Cosmos) 3M and the Start and Start-1 are Russian vehicles, while the Tsyklon-2 is built in the Ukraine. United Start coordinates launches through a Russian partner, Puskovie Uslugi, which since 1998 has had a government charter to market launch services on these boosters. The process of arranging launches through

United Start has been accomplished so far for two U.S. satellites, the QuickBird-1 and EarlyBird-1 commercial imagers.

Capabilities and costs for these launchers are summarized below:

Vehicle	Capabilities (800km SSO [®])	Costs
Tsyklon-2	2850kg	\$20-25M
Start-1	167 kg	\$12M
Start ⁹	220 kg	\$9M
Kosmos 3M	775kg	\$10.5M ¹⁰

United Start has simplified the export process somewhat. The company is awaiting approval of a blanket TAA which will cover all transactions with its Russian and Ukrainian partners. United Start also handles development and coordination of the TTCA. Accordingly, the only action the satellite builder must take, is the submission of an export license request. In United Start's experience, the export license request takes about nine months to process.

Getting a payload on one of United Start's vehicles requires 12 to 18 months' lead time. This includes the time to obtain the export license, get an approved TTCA, etc. Secondary payloads have been carried on Start and Kosmos. A Start launch in March 1985 (the program's only failure so far) carried Israeli and Mexican microsatellites in addition to a 200-kg main payload. In April 1999, a Kosmos 3M launched the Italian Megsat 0 (35kg) with a 550-kg primary satellite.

The Rockot is another Russian vehicle, operated by Khrunichev State Research and Production Space Center from Plesetsk or Baikonur. It is marketed to non-Russian customers by the German-Russian firm Eurockot Launch Services GmbH. The Rockot, a converted RS-18 ICBM, can place 1000 kg in the 800km sun-synchronous orbit. Price is estimated at \$13-15M per vehicle.¹¹ In 1994, the first orbital launch put the 70-kg RS-15 amateur radio satellite in LEO at a 64.8-degree inclination. The launch of NASA's two GRACE science satellites aboard a Rockot in March 2002 cost a (reported) bargain-basement \$8M.¹²

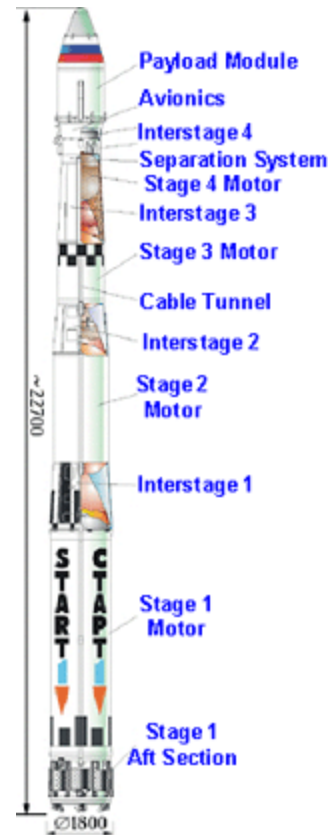


Figure 3. Start launch vehicle. (Puskovie Uslugi)

Another converted ICBM, called the Dnepr, is larger, with a payload capability of up to 4,500 kg to LEO. However, its estimated launch cost of \$10-13 M makes it worth mentioning despite its size. The launch provider is ISC Kosmotras in Moscow. One Stop Satellite Solutions in Utah has an agreement to launch the first batch of Cubesats (modular 10-cm-cube satellites carrying small experiments at very low cost) on a Dnepr.¹³

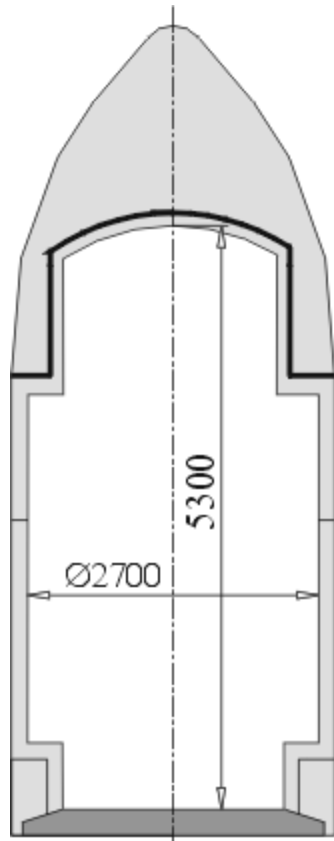


Figure 4. Payload fairing of the Dnepr. Dimensions are in mm. (ISC Kosmotras)

Two converted submarine-launched ballistic missiles (SLBMs), the Vona and the Shtil, are also offered for non-Russian payloads. The Planetary Society's Cosmos-1 solar sail test launch in July 2001 used the suborbital version of the Volna. The Volna carries a 120kg payload to a low (200km) orbit, the Shtil (there are two versions) 100 to 350kg.¹⁴

The EADS Ariane 4 and 5, the largest European launchers, carry the Ariane Structure for Auxiliary Payloads (ASAP). The ASAP ring can host up to eight microsatellites. A November 2001 launch included one large primary payload, the 70-kg STRV1c and STRV1d microsats, and the 650-kg mini-satellite AMSAT 3D (not on the ASAP ring, but centrally on a larger adapter). An ASAP launch on an Ariane 4 was reportedly priced at \$1.2M (1993 dollars).¹⁵ The ASAP ring is compatible with the SPORT module (above).

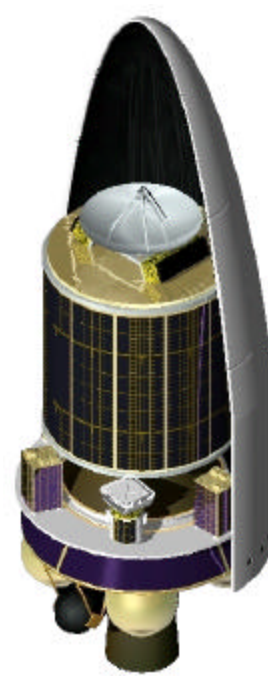


Figure 5. Ariane 5 with ASAP ring and microsats. The central microsat is mounted on a SPORT module. (AeroAstro)

Prospects for Near-term Improvement

There are several projects underway to develop RLVs or new small expendable launchers. While none of these projects has, at this writing, a firm date for first flight, they do promise some new options which may become available in the next few years. Satellite builders may want to contact the relevant organizations well in advance and keep tabs on the availability of these new launchers and the requirements for placing payloads on them.

There are several entrepreneurial efforts to build small expendables. At this writing, the project closest to the operational stage is the Scorpis system from Microcosm. Two suborbital vehicles have been flown, and the first orbital flight (assuming continued funding, which is being supplied by Congress through AFRL) is planned for 2005.¹⁶ The goal of the smallest vehicle in the Scorpis series, the Sprite, is

given by the company as placing 317 kg into a 185-km orbit “for total launch cost of \$1.8 million by tenth production flight.”¹⁷

The Defense Advanced Projects Agency (DARPA) is putting serious funding into the Responsive Access Small Cargo Affordable Launch (RASCAL) project. RASCAL may be called the theoretical descendant of the U.S. Navy’s Project Pilot (a.k.a. NOTSNIK) satellite launcher of the late 1950s. The intended system involves an air-breathing, reusable first stage (modified from an existing aircraft or custom-designed) with an expendable upper stage to place satellites weighing up to 110 kg into LEO for “\$5,000 per pound or less.”¹⁸ In April 2002, DARPA let Phase I study contracts to six companies.

One of those contracts went to Space Launch Corporation, which will develop technology both for RASCAL and a private launch system, the SLC-1, using the same principle. The target for the SLC-1 is 60 kg into 800 km at low inclinations.¹⁹ Other awardees include Coleman Aerospace, Delta V (with Alliant Techsystems), Northrop Grumman (with Orbital Sciences), Pioneer Rocketplane (with HMX), and Space Access. A demonstrator flight by 2006 is hoped for.

Most of the commercial RLV developers have given some thought to launching microsats as primary or secondary payloads. The company furthest along in its vehicle development effort is Kistler Aerospace. The K-1 vehicle now under construction has a payload of 1250 kg into an 800km SSO. Secondary payload opportunities are being actively marketed.

K-1 flights to LEO can carry a reusable Multiple Payload Adapter System (MPAS), based on the same payload interface as the ASAP ring. Up to eight microsattellites can be accommodated as secondary payloads. Ride-sharing opportunities on NASA Add-on Technology Experiment flights, part of NASA’s Space Launch Initiative, should also be available.²⁰

The first flight of the K-1 is expected in late 2003 or early 2004 from Woomera, Australia,

with the date to be announced on completion of financing.. A dedicated K-1 launch to LEO is expected to cost \$17M, to be shared among the payloads as appropriate for each individual flight.

Several other launch options are in development, though none are fully funded. Private projects from companies like JP Aerospace and government proposals like Sandia National Laboratories’ Super Strypi (an orbital version of the Strypi sounding rocket) offer possibilities to keep an eye on for future launches.

Concept: The Small Launch Clearinghouse

In 1997-98, Booz Allen Hamilton developed the SmallSat Catalog Tool for a U.S. military client. This tool was intended to serve the function now performed by NASA’s Access to Space database, but with additional functions and extra help for the first-time user. It started with an Analysis Selection Menu which offered the user three choices:

- “I have a predefined payload, show me shared space vehicles and their launch vehicles.”
- “Show me shared or dedicated launch vehicles for a dedicated space vehicle I would like to build.”
- “Show me a dedicated bus and shared or dedicated launch vehicle for a payload I would like to build.”

The answer led the user to a data input form which included, in addition to the payload requirements, the maximum available funding to support launch of the payload. The tool, using Microsoft Access and Expert Choice decision software, would then ask more questions of the user and steer him/her to the most suitable options, ranked in order of preference to match the user’s prioritization of the various parameters.

The SmallSat Catalog approach was never implemented, as no client was willing to pay for its operation. Limitations of other information sources and tools for the payload builder, especially the beginner, suggest that this concept

can be applied in an updated form to support a nonprofit Small Launch Clearinghouse for all space researchers.

The Clearinghouse need not be a large or expensive operation. It could be run largely by two people, a database/IT administrator and an aerospace engineer or similar expert who could answer questions from researchers about the requirements, compatibility, etc. of their payload with other satellites and launch vehicles. Ideally, funding would also permit adding an administrative expert who could help researchers look for funds, deal with export regulations when required, and find the right points of contact for hardware items, launch providers, and so on.

The Clearinghouse could be run out of NASA as an enhancement to the Access to Space Group's current services, operated by an existing nonprofit like USRA, or contracted out to a private firm. Since NASA is the U.S. agency charged with supporting civil space research, the funding for the Clearinghouse could be a new line item added to the total NASA budget, or an addition to the budget for the Access to Space Group.

An addition of, say, \$200K a year or less to enable universities and other researchers to make better use of space launch opportunities should not be a difficult investment to sell to Congress. Alternatively, the function provided by university-based satellite programs – promoting experience and excitement among space-minded engineering students – should be of enough value to the America space industry that funding could be sought from corporate sources.

The Clearinghouse could also perform an educational function, providing a “road show” briefing and a handbook for prospective satellite builders. The focus of this effort would be on teaching scientists and universities how to perform total mission planning from the beginning, rather than focusing too much on the space hardware and leaving the launch options to be studied toward the end of a project.

The Clearinghouse could also assist military and commercial projects, either on a reimbursable basis or in exchange for an annual budget contribution from DoD and/or industry. Being designed to meet the requirements of researchers, it would include launch opportunities offered by providers in all countries to which U.S. exports are not forbidden.

Conclusion

For the scientific satellite builder, there are no cheap and simple ways to orbit, but options do exist. For now, the Access to Space office, the DoD Space Test Program, and USRA are available to assist the satellite community, as are companies like United Start.

The next question is how to make it as easy as possible for future satellite developers to plan for, locate, and fund launches.

An expansion of the current Access to Space function into a one-stop Small Launch Clearinghouse could perform this function. If the promotion of space science and hands-on space engineering experience is accepted as a worthwhile national goal, the modest funding needed for the Clearinghouse approach is well worth the investment.

Resources

NASA Access to Space Group
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Shtil, Volna:
Contact through Aviaexport,
www.aviaexport.com/English/Contact/Contact.htm

Launch on Cubesat via Dnepr:
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Attn: CubeSat Development
2750 North Fairfield Rd. Ste 1
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Mike Wood, Program Manager
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Web site: www.osss.com/products/cubesatrfq.html

EELV:
ESPA User's Guide:
<http://www.te.plk.af.mil/stp/espa/espa.html>

Ariane (ASAP):
Arianespace Inc.
601 13th Street N.W.
Suite 710 N.
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Tel: 202-628-3936
The ASAP manual is available by clicking on
the "Documents" tab on the page:
www.arianespace.com/index1.htm

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